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Optimization of osmotic drying parameters for beetroot tutti-frutti

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Abstract
Beetroot and beet juice have been known for their antioxidant, anticancer and anti-diabetic effects as well as being a source of dietary nutrients that reduce blood pressure and may improve athletic performance. Osmotic dehydration is one of the most important method of fruits and vegetables preservation. The experiment was laid out in Box Behnken Design with 3 repetitions. The experiment consisted of 17 treatments of various combination of three variables as, sugar syrup temperature (40, 50, 60°C), syrup concentration (50,60,70°Brix) and duration of osmosis (60,120,180 min). For each response, second order polynomial models were developed using multiple regression analysis. Analysis of variance (ANOVA) was performed to check the adequacy and accuracy of the fitted models. The response surfaces and contour maps showing the interaction of process variables were constructed. Sample to solution ratio was taken as 1:4. Sugar gain and water loss was evaluated at different levels for finding the best aftereffects of good quality tutti-frutti of maximum water loss and ideal sugar gain. The treatment 62°Brix sugar concentration, temperature of 50 °C and 105 min duration of osmosis was found optimum for osmotic dehydration of beetroot. At this optimum point, water loss and sugar gain were predicted to be 36.11 per cent and 9.80 per cent respectively.

Keywords: Beetroot, osmotic dehydration, optimization, response surface methodology, water loss, sugar gain

1. Introduction
Fruits and vegetables are important constituents of diet and provide significant quantity of nutrients, especially vitamins, minerals, sugars, and fiber. Beet root commonly known as '*chukander*' are notable for their sweetness, they have the high sugar content. Fresh beetroot also supplies nutritional bonus, their green tops are an excellent source of beta-carotene, calcium, and iron. The beetroot is having tremendous health benefits. However, process of consuming fresh beetroot to meet daily recommended requirement is tedious. The various technologies used for extension of shelf life of the produce include dehydration, osmotic dehydration, intermediate moisture foods, high temperature preservation and low temperature preservation *etc*. In recent years, intermediate moisture foods (IMFs) have become more popular as compared to fully dehydrated foods. Intermediate moisture (IM) fruits and vegetables have advantages over traditionally dried ones, where instead of removing most of the water, just enough water is removed or bound through the addition of a humectant to retard microbial growth (Vibhakara *et al*., 2006) [13].

Osmotic dehydration is a process of partial removal of water by soaking foods, mostly fruits and vegetables, in hypertonic solutions (Shi and Maguer 2002) [9]. Tutti-frutti (from Italian "all fruits", also hyphenated tutti-frutti) is a colourful confection containing various chopped and usually candied fruits, or an artificially created flavouring simulating the combined flavour of many different fruits. Tutti-frutti is also used in cold deserts as toppings for the ice-creams and sundaes. They are also used in sweet pans. The process for making candy product is practically similar to that for preserves in which a whole fruit or its pieces impregnated with sugar or glucose syrup, and afterward drained free of syrup and dried.

Beetroot as a healthy vegetable can be consumed for a long periods by converting it in a powder, tuttti-frutti *etc*. Artificial color addition in tutti-frutti may cause health problems. Beetroot is used as a natural colourant in food processing. Beetroot tutti-frutti does not require artificial color addition because of the red pigment betaline present in it. During the process of product development getting the best combination of variables (temperature, duration and concentration) for good quality product becomes difficult, so the Response surface methodology (RSM) is a statistical procedure frequently used for optimization studies.

It uses quantitative data from an appropriate experimental design to determine and simultaneously solve multivariate problems. The purpose of the present work was to study the effect of osmotic process parameters *viz.* solution temperature, sugar concentration and duration of osmosis on water loss and solid gain and to optimize these parameters for developing higher quality finished product.

2. Material and Methodology

2.1 Sample and solution preparation

The slicing of fresh beetroot was done with the help of stainless steel knife to get 10 mm thick cubes. Syrup of desired sugar concentration (50 to 70° Brix) was prepared by dissolving required amount of sugar in water.

2.2 Osmotic Dehydration of Beetroot A small capacity laboratory temperature controlled water bath of size 30 cm x 20 cm x 20 cm (approximate capacity, 3 liters) was used as osmotic dehydration unit. The unit consists of osmotic dehydration chamber, temperature indicator. The heating chamber made of stainless steel sheet, had an immersion heater (500 W) connected to the bottom of the osmotic chamber. The temperature of the osmotic solution in the chamber was controlled with the help of a thermostat.

Process parameters. The fixed parameters during osmotic dehydration (Jain *et al*., 2011) [4] were;

- Beetroot cubes : 10±0.5 mm (thick)
- Sample weight, g : 40g
- Sample to sugar syrup ratio : 1:4 (w/w)
- Concentration of sugar syrup : 50, 60, 70°Brix
- Sugar syrup temperature, °C : 40, 50, 60°C
- Duration of osmosis, min : 30, 60, 90, 120, 150 and 180.

2.3 Calculation for mass transport data for osmotic dehydration

2.3.1 Water loss (WL)

The water loss (WL) is defined as the net water loss of the fruit during osmotic dehydration on initial weight basis and was estimated as

$$WL = \frac{W_i X_i - W_\theta X_\theta}{W_i} \qquad \text{... 2.1}$$

2.3.2 Mass reduction (MR)

Mass reduction is difference between water loss and solid gain. Also it can be determined as the total weight loss of the fruit on initial weight basis.

$$MR = \frac{W_i - W_\theta}{W_i} \qquad \text{... 2.2}$$

Sugar gain (SG) The sugar gain is the total gain of sugar by the beetroot cubes on initial weight basis. It was determined by using following expression:

$$SG = \frac{W_\theta(1 - X_\theta) - W_i(1 - X_i)}{W_i} \times 100 \qquad \text{... 2.3}$$

From Equations (2.1) and (2.2), the solid gain (SG) can be correlated with mass reduction (MR) and water loss (WL) as

$$SG = WL - MR \qquad \text{…2.4}$$

Where,

WL = Water loss (g per 100 g mass of sample)

SG = Solid gain (g per 100 g mass of sample)

MR = Mass reduction (g per 100 g mass of sample)

W_θ = Mass of beetroot cubes after time θ, g

W_i = Initial mass of beetroot cubes, g

X_θ = Water content as a fraction of mass of beetroot cubes at time θ,

X_i = Water content as a fraction of initial mass of beetroot cubes, fraction.

2.4 Optimization of Input Parameters for Osmotic Dehydration

Response surface methodology (RSM) is useful statistical technique for investigation of complex processes, hence the process parameters for osmotic dehydration of beetroot cubes have been optimized using this techniques. RSM is a collection of certain statistical techniques for designing experiments, building models, evaluating the effects of the factors and searching for optimal conditions for desirable responses (Box *et al*., 1978; Shi *et al*., 2008; Jain *et al*., 2011 and Mehta *et al*., 2013) [2, 10, 7]. In the response surface analysis the experimental values of water losses and solute gain are fitted to a general quadratic polynomial equation and consequently optimizing the values with appropriate optimization software or mathematical solutions. The process parameters such as syrup concentration, syrup temperature and duration of osmosis were optimized for maximum water loss and optimum (targeted) sugar gain.

2.5. Design of experiments

The response surfaces methodology (RSM) deals with the problem of seeking the conditions of an experiment, which are optimal, *i.e.*, most desirable (Myers, 1971). The Box-Behnken design of three variables and three levels including 17 experiments formed by 5 central points was used (Box and Behnken, 1960) for water loss and sugar gain responses. I-optimal design type was selected for optimization of the water activity and color values. In this design quadratic model is used for two variables which has different number of levels (Factor temperature has three levels 40, 50 and 60°C and syrup concentration has three levels 50,60 and 70°Brix) including 16 experiments (run) were formed. The osmotic dehydration was assumed to be affected by three independent variables *viz.*, syrup temperature (T), concentration (C) and duration of osmosis (θ). All these variables were closely controlled and precisely measured during experimentation. The dependent variables, also referred as responses, Y_k (*i.e.*, the percentage of water loss and sugar gain) were measured experimentally.

The independent variables (r_i), the coded variables (x_i) and their levels are shown in Table 1. It is assumed that the mathematical function f_k (k = 1, 2, 3...n), exists for each response variable, Y_k in terms of the processing factors, r_i (i = 1, 2, 3...m), such as

$$Y_k = f_k(r_1, r_2, r_{3,} \ldots r_m) \quad \ldots 2.5$$

The exact mathematical representation of the function (*f*) is either unknown or extremely complex. However, second order polynomial equation of the following form was assumed to relate the response, Y_k and the factors, r_i

$$Y_k = \beta_{ko} + \sum_{i=1}^{i=3} \beta_{ki} x_i + \sum_{i=1}^{i=3} \beta_{kii} x_i^2 + \sum_{i=1}^{i=2} \sum_{j=i+1}^{j=3} \beta_{kij} x_i x_j \quad \ldots 2.6$$

Where, Y_k is response (*i.e.* water loss or sugar gain) β_{ko}, β_{ki}, β_{kii} and β_{kij} are constant coefficients and x_i, the coded independent variables are linearly related to T, C and θ. In practice, the levels of the independent variables change from one application to another. Therefore, the general designs are given in terms of standardized coded variables (x_i), which in any particular application are linearly related to r_i by the following equations.

$$x_i = \frac{(r_i - \bar{r}_i)}{d_i} \quad \ldots 2.7$$

Where,

r_i = Actual value in original units,

$\bar{r}_i$ = Mean of high and low levels of r_i

d_i = Spacing between the low and high levels of r_i.

In present study, n = 2 and m = 3 and hence Eqn. 3.5 can be written as

$$Y_k = f_k(T, C, \theta) \quad \ldots\ldots 2.8$$

Where,

T = Sugar syrup temperature, °C,

C = Sugar syrup concentration, °Brix,

θ = Osmotic dehydration duration,

h and k = Water loss or sugar gain, per cent in osmotic dehydration.

Therefore, Eqn. 3.8 taken the following form as,

$$Y_k = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_3 x_3 + \beta_{11} x_1^2 + \beta_{22} x_2^2 + \beta_{33} x_3^2 + \beta_{12} x_1 x_2 + \beta_{13} x_1 x_3 + \beta_{23} x_2 x_3 \quad .. 2.9$$

Response surface methodology (RSM) was applied to the experimental data using the package, design-expert version 11.0.5 software (Stat-Ease Inc, Minneapolis, USA).

2.6 Design procedure

The experimental layout plan of seventeen experiments for 3 variables and 3 levels of response were performed as enumerated in Table 1 for procuring the water loss and sugar gain as responses for each treatment. To avoid bias, 17 runs were performed in a random order for estimation of the constants of Eqn. (2.9). The decision for the range and centre points of the variables was taken through preliminary trial experiments. Experimental layout plan of various experiments for 3 variables and 3 levels responses is presented in Table 1. Sugar gain by the beetroot cubes during osmotic dehydration which a key factor is influencing its quality and marketability, which was considered an important parameter for the optimization of the input factors of the process.

2.7 Numerical optimization

Numerical optimization technique of the Design-Expert version 11.0.5 software was used for simultaneous optimization of the various responses. The desired goals for each factor and response were chosen. The goals may apply to either factors or responses. The possible goals are: maximize, minimize, target, within range, none (for responses only). All the independent factors (T, C and θ) were kept in range while the responses *viz.*, water loss was kept maximized and sugar gain was kept targeted.

2.8 Graphical optimization

Graphical optimization technique of design-expert software was carried out for obtaining the desired qualities in final product. For graphical optimization, super- imposition of contour plots for all responses was done with respect to process variables using Box Behnken model of design expert version 11.0.5 software. The superimposed contours of all responses for syrup concentration, syrup temperature and duration of osmosis and their intersection zone for maximum water loss and targeted sugar gain indicated the ranges of variables which were taken into account as the appropriate range for best product quality in terms of responses. The optimum combinations of product and process variables for osmotic dehydration of beetroot cubes were derived by averaging those ranges of variables.

2.9 Verification of optimum responses

The optimum responses were verified by conducting the osmotic dehydration experiment under optimum conditions. The responses such as water loss and sugar gain at optimum processing conditions were compared with the values which were predicted by the mathematical model.

3. Result and Discussion

The process parameters (sugar concentration, solution temperature and duration of osmosis) were optimized for maximum water loss and optimum salt gain. This optimum sugar gain was decided by taking sensory evaluation of beetroot tutti frutti samples having different sugar gain levels. Values of various responses (water loss and sugar gain) at different experimental combinations for coded variables are given in Table 1.

Table 1: Experimental layout for 3 variables and 3 levels response surface analysis

	Coded value			**decoded value**			
Treatment No.	**Syrup temp., °C**	**Syrup conc. °Brix**	**Duration of osmosis, min**	**Initial Moisture Content (percent)**	**Final moisture content (percent)**	**Water Loss (percent)**	**Sugar gain (percent)**
	$x_{1(T)}$	**$x_{2(C)}$**	**$x_{3(\theta)}$**	**T**	**C**	**θ**	
1	60(1)	60(0)	180(1)	85.36	70.18	552.18	11.99
2	40(-1)	70(1)	120(0)	85.36	67.42	33.23	9.67
3	40(-1)	60(0)	60(-1)	85.36	74.24	23.60	6.89

4	50(0)	60(0)	120(0)	85.36	66.50	36.35	9.67
5	60(1)	60(0)	60(-1)	85.36	66.45	39.08	9.14
6	60(1)	50(-1)	120(0)	85.36	63.57	43.10	9.32
7	40(-1)	60(0)	180(1)	85.36	66.52	36.15	8.99
8	60(1)	70(1)	120(0)	85.36	56.15	52.12	12.35
9	50(0)	50(-1)	180(1)	85.36	67.68	35.08	8.84
10	50(0)	60(0)	120(0)	85.36	66.60	36.40	9.84
11	50(0)	60(0)	120(0)	85.36	66.52	36.37	9.72
12	50(0)	70(1)	60(-1)	85.36	68.87	32.08	9.18
13	50(0)	50(-1)	60(-1)	85.36	74.20	23.37	6.75
14	40(-1)	50(-1)	120(0)	85.36	72.12	26.36	7.21
15	50(0)	70(1)	180(1)	85..36	54.81	52.26	12.00
16	50(0)	60(0)	120(0)	85.36	66.60	36.40	9.81
17	50(0)	60(0)	120(0)	85.36	66.53	36.45	9.87

3.1 Effect of osmotic parameters on sugar gain

The sugar gain during the osmotic dehydration was found to be dependent on the syrup temperature, concentration and duration of osmosis. Therefore, the process parameters such as syrup temperature, concentration and duration of osmosis were optimized using the response surface technique. A second order polynomial equation Eqn. (2.6) was fitted with the experimental data presented in Table 1.

Eqn. (3.1) gives the predicted sugar gain, per cent as a function of syrup temperature (x_1), concentration (x_2) and duration of osmosis (x_3) expressed in coded form. This equation was obtained using step-down regression method where factors with F-values less than one were rejected as described by Snedecor and Cochran (1967) [11]. The data for sugar gain were analyzed for stepwise regression analysis as shown in Table 2. The quadratic model was fitted to the experimental data and statistical significance for linear and quadratic terms was calculated for sugar gain as shown in Table 2.

The presence of quadratic terms of concentration of syrup and duration of osmosis indicated curvilinear nature of response surface. The quadratic terms of concentration of syrup and duration of osmosis were also highly significant at 1 per cent level while interaction terms of temperature of syrup and duration of osmosis as well as concentration of syrup and duration of osmosis were also significant at 5 per cent level. The comparative effect of each factor on sugar gain would be observed by the F values in the ANOVA (Table 2). The higher F values indicated that syrup concentration (F = 1912.08) was the most influencing factor followed by temperature of syrup (F= 1569.98) and syrup time (F = 1514.19). The R^2 value was calculated by least square technique and found to be 0.998 showing good fit of model to the data.

The model F value of 575.18 implies that the model is significant ($P < 0.0001$). The linear terms (T, C and θ) are significant ($P < 0.0001$). The lack of fit F-value of 1.32 implies the lack of fit is not significant relative to the pure error, which indicates that the developed model was adequate for predicting the response. Moreover the predicted R^2 of 0.988 was in reasonable agreement with adjusted R^2 of 0.996. This revealed that the non-significant terms have not been included in the model. Therefore this model could be used to navigate the design space. High value of coefficient of determination (R^2=0.998) obtained for response variable indicated that the developed model for sugar gain accounted for and adequately explained 99.80 per cent of the total variation.

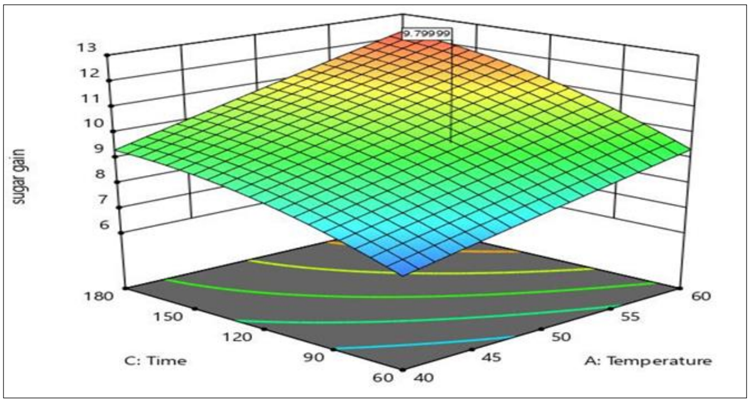
The result of analysis of variance indicated that the linear terms of syrup temperature, syrup concentration and duration of osmosis were highly significant at 1 per cent level (Table 2). The comparative effect of each factor on sugar gain could be observed by F values in the ANOVA (Table 2). The higher F values indicated that syrup concentration (F =1912.08) was the most influencing factor followed temperature of syrup (F = 1569.98) and by duration of osmosis (F = 1514.19) was least effective over sugar gain.

Table 2: ANOVA for sugar gain during osmotic dehydration of beetroot cubes

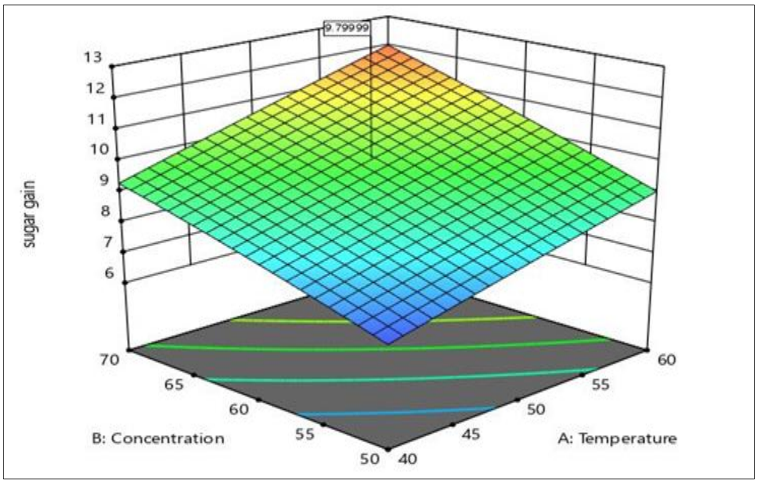
Source	Sum of Squares	df	Mean Sum of Squares	F-value
Model	41.55	9	4.62	575.18**
A-temperature	12.6	1	12.6	1569.98**
B-concentration	15.35	1	15.35	1912.08**
C-time	12.15	1	12.15	1514.19**
AB	0.0812	1	0.0812	10.12*
AC	0.1406	1	0.1406	17.52*
BC	0.1332	1	0.1332	16.6*
A^2	0.0075	1	0.0075	0.9365**
B^2	0.044	1	0.044	5.49**
C^2	0.9996	1	0.9996	124.55**
Residual	0.0562	7	0.008	
Lack of Fit	0.0279	3	0.0093	1.32ns
Pure Error	0.0283	4	0.0071	
Cor Total	41.6	16		
Std. Dev.	0.0896			
Mean	9.48			
C.V. %	0.9445			
R^2	0.9986			

Adjusted R²	0.9969			
Predicted R²	0.9882			

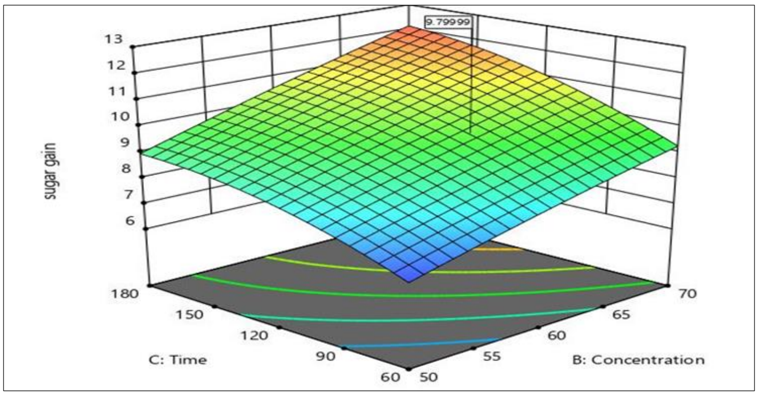
** Significant at 1per cent level, *Significant at 5 per cent level, ns - Non significant



1. At concentration of syrup (60°Brix)



2. At (105 min) duration of osmosis



3. At 60°C syrup temperature

Fig 1: Response surface showing the effect of temperature and concentration at duration (105 min) on sugar gain during osmotic dehydration

The regression equation describing the effects of process variables on sugar gain in terms of coded values of variable is given as:

SG= 9.78 + 1.26 x_1+1.39x_2+1.24x_3 +0.1425 $x_1 x_2$ +.01800 x_1 x_3+0.1825x_2 x_3-0.04x_1^2-0.09x_2^2 -0.49x_3^2 ...3.1 (R^2 =0.988)

Replacing x_1, x_2 and x_3 with (T-50)/10, (C-60)/10 and (θ–120)/60 respectively [Eqn. (3.7)] in Eqn. (3.1), the sugar gain in real terms of syrup temperature, concentration and duration of osmosis can be given by

SG= -5.6142+0.0447 T +0.1534 C +0.0191 θ + 0.0014TC +0.0003 Tθ +0.0003 Cθ-0.0004 T^2 -0.0010 C^2 -0.0001 θ^2 …3.2

The linear positive terms [Eqn. (3.2)] indicated that sugar gain increased with increase in syrup temperature, syrup concentration and duration of osmosis. The negative values of quadratic terms of temperature of syrup and duration of osmosis indicated that higher values of these variables further reduced sugar gain. To visualize the combined effect of two variables on the sugar gain, the response surface and contour plots (Fig. 1) were generated for the fitted model as a function of two variables while keeping third variable at its central value.

3.2 Effect of osmotic parameters on water loss

The variation in water loss by changing syrup temperature, concentration and duration of osmosis has been presented in Table 1. A second order polynomial equation [Eqn. (2.6)] was fitted with the experimental data presented in Table 1. Eqn. (3.3) gives the predicted water loss, per cent as a function of syrup temperature (x_1), concentration (x_2) and duration of osmosis (x_3) expressed in coded form. This equation was obtained using step-down regression method where factors with F-values less than one were rejected as described by Snedecor and Cochran (1967) [11]. Data for water loss were analyzed with the help of the Response Surface Methodology (RSM) by using the package, design-expert version 11.0.5.0 software (Stat-Ease Inc, Minneapolis, USA) as shown in Table 3.

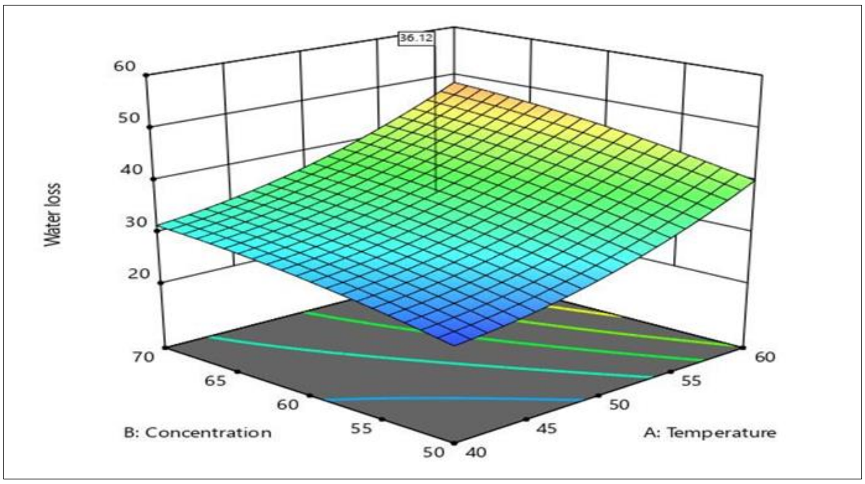
The quadratic model was fitted to the experimental data and statistical significance for linear, quadratic and interaction terms was calculated for water loss as shown in Table 3.

The R^2 value was calculated by least square technique and found to be 0.999 showing good fit of model to the data. The model F value of 1953.76 implies that the model is significant ($P< 0.0001$). The linear terms (T, C & θ) are significant ($P< 0.0001$). The lack of fit F value was not significant which indicates that the developed model was adequate for predicting the response. Moreover the predicted R^2 of 0.994 was in reasonable agreement with adjusted R^2 of 0.999. This revealed that the non-significant terms have not been included in the model. Therefore this model could be used to navigate the design space.

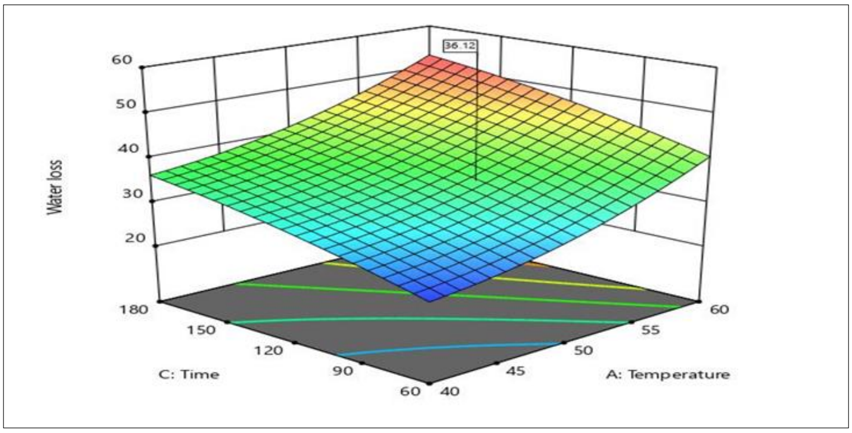
Table 3: Analysis of variance for water loss during osmotic dehydration of beetroot cubes

Source	Sum of Squares	df	Mean Sum of Square	F-value
Model	298.44	9	33.16	1953.76**
A-temp	96.19	1	96.19	5667.43**
B-syrup cons	113.93	1	113.93	6712.74**
C-time	70.86	1	70.86	4175.34**
AB	0.2256	1	0.2256	13.29*
AC	2.18	1	2.18	128.19*
BC	1.08	1	1.08	63.73**
A^2	1.45	1	1.45	85.19**
B^2	1.64	1	1.64	96.44**
C^2	9.77	1	9.77	575.82**
Residual	0.1188	7	0.017	
Lack of Fit	0.0933	3	0.0311	4.88 ns
Pure Error	0.0255	4	0.0064	
Cor Total	298.55	16		
R^2	0.9996			
Adjusted R^2	0.9991			
Predicted R^2	0.9949			
Std. Dev.	0.1303			
Mean	32.18			
C.V. %	0.4049			

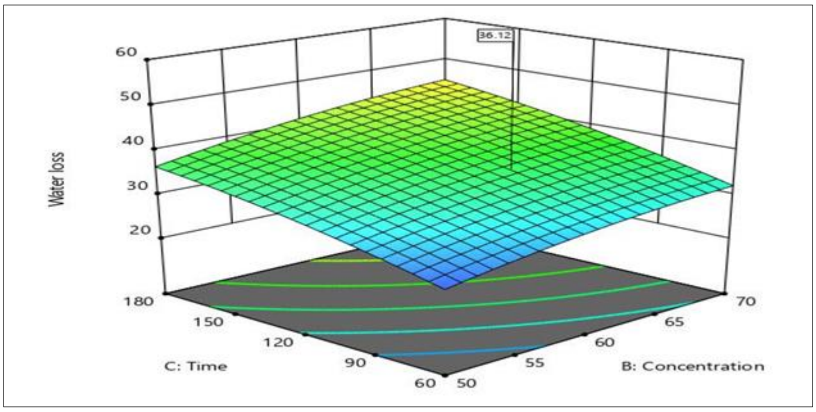
** Significant at 1per cent level, *Significant at 5 per cent level, ns - Non significant



1. At 105 min duration of osmosis



2. At 60°Brix concentration of syrup



3. At 50°C temperature of syrup

Fig 2: Response surface showing the effect of temperature and concentration at duration (105 min) on water loss during osmotic dehydration.

High value of coefficient of determination ($R^2 = 0.999$) obtained for response variable indicated that the developed model for water loss accounted for and adequately explained 99.90 per cent of the total variation. The result of analysis of variance of Eqn. (3.3) indicated that the linear terms of syrup temperature, syrup concentration and duration of osmosis were highly significant at 1 per cent level (Table 3).

The regression equation describing the effects of process variables on water loss in terms of coded values of variable is given as:

$$WL = 33.46 + 3.47\,x_1 + 3.77x_2 + 2.98x_3 + 0.2375\,x_1x_2 + 0.7375\,x_1\,x_3 + 0.5200x_2\,x_3 - 0.5860x_1^2 - 0.6235x_2^2 - 1.52x_3^2 \quad \ldots.3.3$$

($R^2 = 0.999$)

Replacing x_1, x_2 and x_3 with (T-50)/10, (C-60)/10 and (θ–120)/60 respectively [Eqn. (3.7)] in Eqn. (3.3), the water loss in real terms of syrup temperature, concentration and duration of osmosis can be given by,

$$WL= -34.920 + 0.642\ T + 0.9028\ C + 0.037\theta + 0.0023\ TC + 0.0012\ T\theta + 0.0008\ C\theta - 0.0058\ T^2 - 0.0062\ C^2 - 0.0004\ \theta^2 \quad \ldots\ldots3.4$$

The linear positive terms [Eqn. (3.4)] indicated that water loss increased with increase in syrup temperature, syrup concentration and duration of osmosis. The presence of positive interaction terms between syrup temperature and concentration, temperature and duration of osmosis and concentration and duration of osmosis indicated that increase in their levels increased water loss. The negative values of quadratic terms of syrup concentration and duration of osmosis indicated that higher values of these variables reduced water loss. To visualize the combined effect of two variables on the water loss, the response surface and contour plots (Fig 3) were generated for the fitted model as a function of two variables while keeping third variable at its central value. The water loss increased rapidly in the early stages of osmosis, after which the rate of water loss gradually slowed down with time. Rapid removal of water in early stages of osmosis has been reported for apple (Conway *et al*. 1983) [3], carrots (Uddin *et al*. 2004) [12] etc.

3.3 Numerical optimization of osmotic dehydration of beetroot

Numerical multi responses optimization technique was carried out for the optimizing process parameters of the osmotic dehydration of beetroot cubes. To perform this operation, Design expert version 11.0.5.0 of the STAT-EASE software (Statease Inc, Minneapolis, USA,), as discussed in section 3.5.2.1 was used for simultaneous optimization of the multiple responses.

The constraints were set such that the selected variables such as temperature (T), concentration (C), and duration of osmosis (θ) would be minimum from economical point of view for the most important product attribute and close to the optimum for the others (Jain *et al*. 2011) [4]. The main criteria for constraints optimization were maximum possible water loss and targeted sugar gain of 9.80 per cent was based on panel evaluation results as most important quality (sweetness) attribute.

The desired goals for each factor and response are shown in Table 4. In order to optimize the process parameters for osmotic dehydration process by numerical optimization which finds a point that maximizes the desirability function; equal importance of '3' was given to all the 3 process parameters (T, C and θ) and 2 responses (water loss and sugar gain). The goal setting begins at a random starting point and proceeds up the steepest slope on the response surface for a maximum value of water loss and targeted value of sugar gain. Table 5 shows the software generated optimum conditions of independent variables with the predicted values of responses.

Table 4: Optimization criteria for different process variables and responses for osmotic dehydration of beetroot cubes

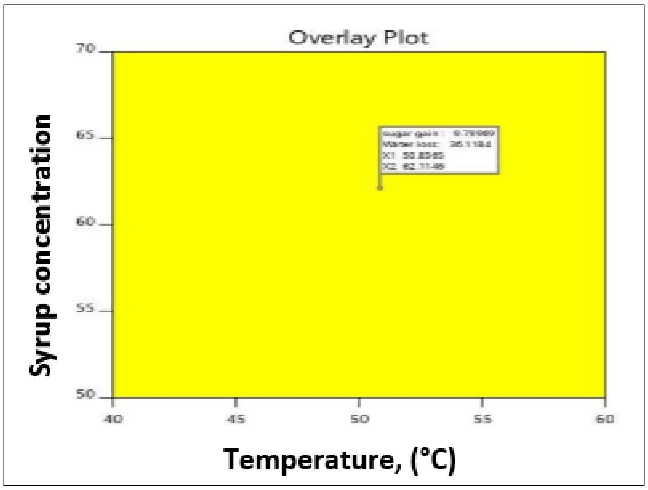
Parameter	Goal	Lower limit	Upper limit
Syrup temp, ºC	In range	40	60
Syrup concentration, ºBrix	In range	50	70
Syrup duration, min	In range	60	180
Water loss, per cent	Maximize	23.32	52.25
Sugar gain, per cent	target = 9.80	6.75	12.35

Table 5: Optimized process parameters for osmotic dehydration of beetroot cubes

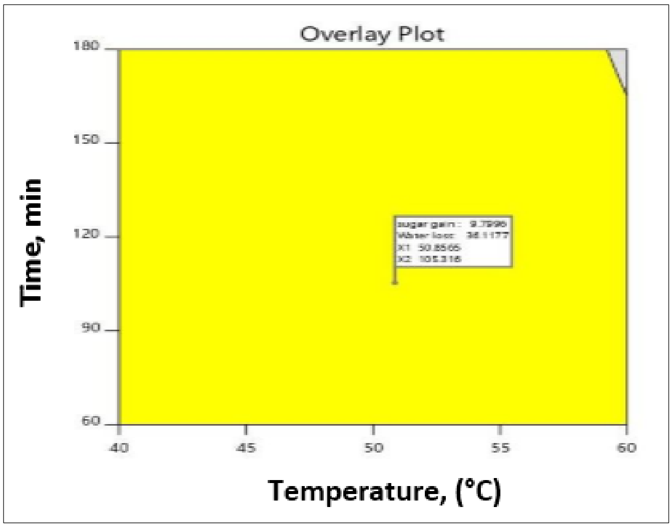
No.	Temperature, ºC	Concentration, ºBrix	Duration, min	Water loss, per cent	Sugar gain, per cent
1	49.85≈50	62.04≈62	105.31≈ 105	36.11	9.79

3.4 Graphical optimization

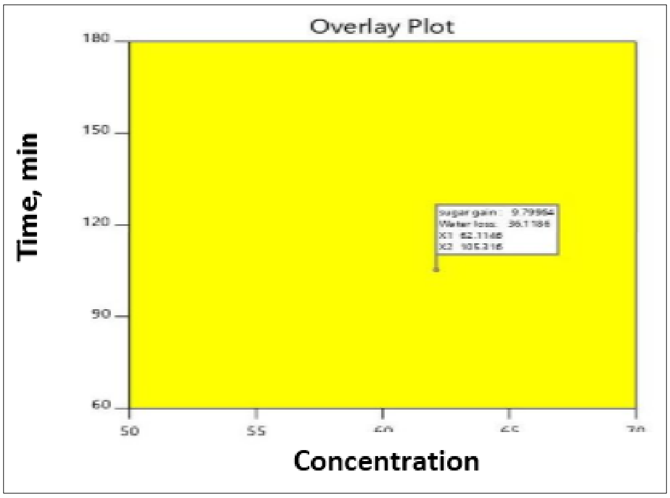
A graphical multi-responses optimization technique was adapted to determine the workable optimum conditions for the osmotic dehydration of beetroot cubes. The contour plots for all responses were superimposed and regions (yellow regions) that best satisfy all the constraints were selected as optimum conditions. The criteria for constraint optimization are already given in Table 4. Superimposed contour plots having common superimposed area for all responses for osmotic dehydration of beetroot cubes are shown in Fig. 3.



(A) At 105 min duration of osmosis



(B) At 62°Brix concentration of syrup



(C) At 50 °C temperature of syrup.

Fig 3: Overlay plots for water loss (%) and sugar gain (%) for osmotic dehydration of beetroot cubes.

3.5 Verification of the model for osmotic dehydration of beetroot cubes

Osmotic dehydration experiments were conducted at the optimum process conditions (Temperature = 50 ºC, Concentration = 62º Brix and Duration = 105 min) for testing the adequacy of model equations for predicting the response values. The observed experimental values (mean of 3 experiments) and values predicted by the equations of the model are presented in Table 6. The experimental values were found to be very close to the predicted values for water loss and sugar gain, with the value of C.V. as 0.22 and 0.40 per cent respectively. Therefore, it could be concluded from above discussion that model Eqns. (4.5) and (4.7) are quite adequate to assess the behavior of the osmotic dehydration.

Table 6: Predicted and experimental values of responses at optimized osmosis process conditions

Response	Predicted value	Experimental value*	Std. Dev. (±)	C.V., per cent
Water loss, per cent	36.11	36.01	0.10	0.22
Sugar gain, per cent	9.79	9.67	0.04	0.40

* Average of three replications.

4. Conclusion

The process parameters for the beetroot tutti frutti were optimized using RSM. With respect to the water loss and sugar gain the linear, quadratic and interaction effects of three variables were analysed. Analysis of variance (ANOVA) was performed to check the adequacy and accuracy of the fitted models. The response surfaces and contour maps showing the interaction of process variables were constructed. The result of analysis of variance indicated that the linear terms of syrup temperature, syrup concentration and duration of osmosis were highly significant at 1 per cent level for both the responses *viz.* water loss and sugar gain. The F values indicated that syrup concentration was the most influencing factor followed by temperature of syrup and duration of osmosis for both the responses *viz.* water loss and sugar gain. As per graphical optimization technique, the superimposed contours of all responses for concentration of syrup (C), temperature of syrup (T) and duration of osmosis (θ) and their intersection zone for maximum water loss and targeted sugar gain (9.80 per cent) indicated the range of optimum values of process variables as follows Temperature of syrup 50ºC Concentration of syrup 62ºBrix, Duration of osmosis 105 min. At this optimum point, water loss and sugar gain were predicted to be 36.12 and 9.80 per cent, respectively.

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